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ARS SPECIAL REPORT

Fertilizers Applied In Liquid Forms

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Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

SUMMARY

Fertilizers that are directly applied in liquid forms are fast gaining popularity among farmers in this country, and survey figures for the year ending June 30, 1955, show that use has reached 709,836 tons exclusive of liquid mixtures.

The liquid fertilizers are time-saving and labor-saving. They do require specialized equipment. However, ways of reducing the equipment investment are being developed by research.

When properly applied, the liquid nutrients are as effective as solids for promoting plant growth.

Anhydrous ammonia, which is held and applied under high pressure, has consistently outranked other liquid fertilizers in tonnage. Lately, water solutions of nitrogen compounds, some applied under low pressure and some requiring no pressure, have gained favor rapidly. Tonnage of nitrogen solutions almost equals that of anhydrous ammonia.

Liquid mixtures account for a relatively small proportion of the liquid fertilizer tonnage total, but their use also is increasing and spreading to new areas.

Information in this report was provided by the Soil and Water Conservation Research Branch and the Agricultural Engineering Research Branch, Agricultural Research Service

FERTILIZERS APPLIED IN LIQUID FORMS

Fertilizers applied in liquid forms--to provide nitrogen in particular, but other plant nutrients also--are fast gaining popularity among farmers in the United States.

As alternatives for solid fertilizers, liquids are being applied to a variety of crops, such as corn, cotton, small grains, forage crops, vegetables, and fruit and nut trees. Some types of liquid fertilizers are adaptable to a wide range of farming practices from preplant treatments to top dressings and as additions to irrigation water in either sprinkler or ditch systems.

Use of liquid fertilizers (not including mixtures) in this country's farming has soared from 40,529 tons in 1946-47 to 709,836 tons in 1954-55, and the upward trend is expected to continue--though liquid forms may never rival the huge tonnages of conventional dry fertilizer materials. Liquid fertilizers in 1954-55 represented 3.1 percent of total fertilizer tonnage.

LIQUID FERTILIZERS COMPARED WITH SOLID

Compared with solid fertilizers, from the farmer's standpoint--

--Liquid fertilizers are labor-saving. There are no heavy bags to handle. The liquid fertilizer is moved from source to applicator equipment by hydraulic means thereby requiring no muscular exertion.

--Application of liquid fertilizers is often faster. Many fertilizer containers for solutions are larger on field machines and worth-while amounts of time are saved.

--Liquid fertilizers are frequently cheaper than solids. The most-used liquid fertilizers cost less per unit of plant nutrient.

--Generally speaking, nutrients in liquid forms can be applied at rates comparable to those used for solids.

--Nutrients in liquid forms, when properly applied, are likely to be as effective as solids for promoting vigorous plant growth.

--Liquid fertilizers require specialized application equipment, and the cost involved is commonly cited as the main disadvantage of using the materials in farming. Ways of reducing the equipment investment are being developed by research. Also, a good deal of application work is done for farmers by dealers and service agencies, relieving the farmer of an equipment investment.

DEVELOPMENT OF LIQUID FERTILIZERS

The possibility of applying fertilizer in liquid form was tentatively explored more than a century ago, when the fertilizer industry was getting its start. Ammonia was recognized as a good source of the nitrogen that plants require, and research in Europe, about 1850, included some tests with a solution of ammonia in water. However, farm use of liquid fertilizers remained far in the future.

The idea of treating crops with liquid nutrients was revived in the 1920's, when commercial production of synthetic ammonia was launched in the United States. Pioneers in trying out liquid fertilizers were growers in Hawaii and California. California growers began applying liquid mixed fertilizers to crops in irrigation water in the early 1920's, and in the early 1930's made similar use of anhydrous ammonia.

The rapid advance in liquid fertilizer production began after World War II, when a number of ammonia plants which the Government had held for manufacture of munitions were sold or leased to private industry.

TYPES OF LIQUID FERTILIZERS

Liquid fertilizers are commonly grouped in either of two ways:

1. According to pressure requirements.
2. According to their plant nutrient content.

Pressure grouping is followed mainly in this report because the pressure factor is basic to a farmer's planning for use of liquid fertilizer and the equipment that he may need.

Liquid nitrogen fertilizers are marketed for farm use in high-pressure, low-pressure, and nonpressure forms, though not all of these types may be available for choice in a given farm area. Liquid phosphoric acid and liquid mixed fertilizers are nonpressure solutions.

High-Pressure Liquid--Anhydrous Ammonia

The one liquid fertilizer which must be kept under high pressure during farm storage and use is anhydrous ammonia. It contains 82 percent nitrogen--an extremely high concentration compared with other nitrogen-carrying fertilizers.

Anhydrous ammonia exerts a gauge pressure of 211 pounds per square inch at a temperature of 104°F. The lower the temperature, the less pressure it takes to keep the gas liquefied. At 75°F., for example, the required pressure is 126 pounds.

When released from pressure, anhydrous ammonia evaporates rapidly, but loss during application can be kept small with proper handling.

- *When anhydrous ammonia is applied to soil, it should always be injected in deep furrows and quickly covered. In the fine-textured soils, which retain nitrogen best, anhydrous ammonia requires 4 to 6 inches of soil cover to seal in the nitrogen. An additional inch or two of soil cover is advisable in light (sandy) soils.

- *When anhydrous ammonia is added to irrigation water, loss is minimized by applying the liquid in the cooler hours of the day and in calm weather, because evaporation is greater at high temperatures and also when wind ruffles the water.

Low-Pressure Solutions

Low-pressure liquid fertilizers are solutions of nitrogen compounds in water. Their nitrogen content is not more than half that of anhydrous ammonia on a weight basis. On a volume basis, a 100-gallon tankful of nitrogen solution will supply approximately the same amount of nitrogen as a 100-gallon tankful of anhydrous ammonia. Some low-pressure liquid fertilizers consist of ammonia in water, and these are generally known as aqua ammonia solutions. Others contain ammonia with ammonium nitrate and urea added singly or in combination.

Pressure requirements of these solutions are due to the free ammonia they contain. Low-pressure solutions are those exerting pressures ranging up to 25 pounds per square inch at 104° F. The pressure is much lower at the temperatures that usually prevail when the solutions are applied.

When low-pressure solutions are applied, nitrogen loss to the air is minimized by means similar to those described for conserving anhydrous ammonia except that the soil cover can be shallower. In any case a solution should be placed at least 2 inches below the surface of the soil. The solution should also be at least 2 inches from the seed to avoid seed injury.

Diluting a low-pressure nitrogen solution with additional water may be advantageous in some circumstances. For example:

*In hot weather, if a farmer dilutes a solution enough to reduce vapor pressure practically to zero, he minimizes loss of nitrogen to the air and chance of vapor lock in a pump or hose line.

*If a farmer has only a low-pressure nitrogen solution and wishes to apply it on ground surface, he can do this by first diluting the solution enough to reduce vapor pressure practically to zero. Nitrogen loss will then be minor.

Table 1 provides some information on which decisions can be based as to whether dilution would be advisable and how much the solution should be diluted to minimize nitrogen loss. The nitrogen content of a solution before and after dilution is a guide to the increased quantity of a diluted solution needed in order to maintain the desired nitrogen application rate. Handbooks of commercial concerns give more complete tables on water-pressure ratios for the nitrogen solution fertilizers.

Nonpressure Liquids--Single and Mixed Nutrients

Nonpressure liquid fertilizers are water solutions of single or mixed nutrients. The nitrogen sources are generally ammonium nitrate or urea--never free ammonia. The phosphorus source materials are usually phosphoric acid or ammonium phosphates. Liquid fertilizer mixtures used in the West commonly contain only 2 primary plant nutrient elements--nitrogen and phosphorus. In other areas, mixtures frequently include potassium also. Secondary or trace nutrient elements are occasionally included in liquid mixtures.

Aside from one special situation, nonpressure liquid fertilizers do not lose nutrients by evaporation and may be applied in any preferred way: deposited in or on the soil; sprayed on the soil; added to irrigation water; applied by overhead irrigation. When overhead irrigation is used, the solution should be applied at the beginning of the irrigation or should be dilute enough to avoid crop injury.

Table 1.--Amount of water needed to reduce vapor pressure of typical low-pressure nitrogen solutions to approximately zero

Commercial low-pressure solution		Vapor pressure at 104° F.	Gallons of water per 100 gallons of solution needed to reduce vapor pressure to approximately zero at--		Nitrogen content after solution is diluted to zero pressure with water at--	
Total nitrogen	Free ammonia nitrogen		78° F.	104° F.	78° F.	104° F.
Percent	*Percent*	*Pounds per square inch*	*Gallons*	*Gallons*	*Percent*	*Percent*
41.0	18.3	10	0.0	34.2	41.0	31.5
41.0	21.6	17	5.4	43.2	39.0	29.5
37.0	13.7	1	0.0	2.4	37.0	36.3
33.5	21.4	12	2.9	23.9	32.8	23.9
33.5	28.0	23	14.5	54.2	29.1	22.3

The exceptional situation of a chemical reaction involving nitrogen loss occurs when a nonpressure solution containing ammonium salts is applied to alkaline soil or added to alkaline irrigation water. If this type of solution is applied to alkaline soil, a shallow soil cover may be needed to avoid nitrogen loss. If the solution is added to alkaline irrigation water, minor loss of nitrogen may be expected.

Liquid fertilizers of nonpressure types are sometimes wanted for special purposes, such as applying a starter solution of a complete mixture to a vegetable crop at transplanting time. . .or fertilizing a lawn or small garden. . .or for greenhouse work. For small-scale requirements, such as these, users often get solid nutrient materials and make up solutions. If solids are bought, it is important that they be water-soluble. Some solids that are water-soluble singly may salt out if combined in a liquid mixture. If materials cannot be selected with assurance of avoiding this problem, a user can only try out small quantities of available materials in solutions and thus learn which materials prove satisfactory. Among the specialty solid products that can be made up into solutions are compounds of minor nutrient elements, such as boron, copper, and zinc. Dilute sprays of these minerals are sometimes needed for tree crops.

SALTING OUT

In certain situations, fertilizer solutions may salt out--that is, some of the dissolved materials may crystallize and settle. If this occurs, the crystals may form a troublesome sludge which clogs hose lines when the liquid is applied. Furthermore, the composition of the fertilizer is altered.

Salting out presents a cold weather problem. In general, the lower the temperature, the more likely a solution is to salt out. Commercial nitrogen solutions, however, differ widely in salting-out temperature--ranging from about 58°F. to -31°F. These differences in products are due not only to the materials in a solution but also to the solution strength.

A farmer has no instant remedy against sludge if a fertilizer solution salts out while he is applying it in the field.

A farmer's best precaution against salting out is to choose a solution with low enough salting-out temperature for his climate. As an emergency

Table 2.--Nitrogen content and salting-out temperatures, before and after dilution, of typical commercial nitrogen fertilizer solutions which normally salt out above 0° F.

Nitrogen content and salting-out temperatures of commercial nitrogen fertilizer solutions	3 gallons water added to 100 gallons commercial solution		5 gallons water added to 100 gallons commercial solution		10 gallons water added to 100 gallons commercial solution		15 gallons water added to 100 gallons commercial solution	
	Nitrogen content	Salting-out temperature	Nitrogen content	Salting-out temperature	Nitrogen content	Salting-out temperature	Nitrogen content	Salting-out temperature
Low-pressure solutions:	*Percent*	*Degrees F.*	*Percent*	*Degrees F.*	*Percent*	*Degrees F.*	*Percent*	*Degrees F.*
41.0% N (21° F.).............	39.8	19	39.2	18	37.7	16	36.2	15
37.0% N (56° F.).............	36.1	50	35.6	48	34.2	42	33.0	37
33.5% N (18° F.).............	32.4	*	31.8	*	30.5	*	29.2	*
Nonpressure solutions:								
32.0% N (32° F.).............	31.2	24	30.8	21	29.8	12	28.8	5
21.0% N (51° F.).............	20.6	48	20.2	45	19.5	38	18.8	32
20.0% N (58° F.).............	19.6	54	19.4	51	18.7	44	18.1	36

* Below 18° F.; more exact data not available.

precaution in unusually cold weather--which may occur when fertilizer is applied in early spring or late fall--he can lower the salting-out temperature of a solution by adding water to dilute it. Table 2 gives some guidance for this, showing effects of various dilutions. Commercial handbooks provide more detailed information.

CUSTOM APPLICATION VERSUS FARMER APPLICATION

Custom Application

A good deal of liquid fertilizer is applied for farmers by dealer or service organizations. This arrangement relieves the farmer of need to invest in equipment and of the labor and time he would spend fertilizing crops. One disadvantage to be considered is that a long rainy spell may disrupt a custom operator's schedule, causing more delay to some customers than if they relied on their own equipment.

Custom charges for applying liquid fertilizers to the soil vary from one locality to another, commonly ranging in recent years from $1.50 to $3 per acre. Application of liquid fertilizers in irrigation water is usually done by dealers as part of the sales arrangement.

Farmer Application

A farmer who chooses a liquid fertilizer may find it advantageous to obtain his own equipment in situations such as the following: If the equipment will be used enough to make the investment economically worth-while; if it is important to have equipment on the farm, ready when wanted.

Field applicator equipment for liquids can be obtained in 2 ways: A farmer or group of farmers can buy the needed items. A farmer or group may be able to rent equipment if a bulk supply center for liquid fertilizer is near.

If a liquid fertilizer is to be extensively used, a farmer or group may wish to invest, not only in field equipment, but also in a storage tank for the advantages of having 1,000 or more gallons at hand, and of buying at a better price.

Cost studies of one type of field applicator equipment--a metering hose pump--provide some guidance on the amount of use that justifies ownership, economically. The pump cited in these studies is an improved type weighing less than 25 pounds and equipped with plastic hoses. It was developed jointly by the ARS and the North Carolina Agricultural Experiment Station. The pump can be used with low-pressure and nonpressure nitrogen solutions and liquid mixtures, but not with anhydrous ammonia. It is described in "Hose Pump for Applying Nitrogen Solutions," FB-2096.

The cost of the improved pump in different models and with associated equipment is usually under $250. The cost studies provide two comparisons:

1. Compared with custom application, a farmer who invested $200 in the hose pump assembly would break even if he used the pump on 31 acres yearly.

2. Compared with the cost of applying solid fertilizer by attachments to the farmer's own planter-distributor, the break even point for the investment of $200 in hose pump assembly would call for annual use on about 22 acres.

These figures are based on an application rate of 60 pounds of nitrogen per acre at North Carolina prices.

EQUIPMENT

Equipment suitable for applying one type of liquid--high-pressure, low-pressure, or nonpressure--may not suit another type. For example, container material that is adequately corrosive-resistant for a specific type of liquid may not be serviceable for another. Following are suitable kinds of equipment in common use:

For high-pressure anhydrous ammonia. . .

Containers: Steel capable of withstanding pressures of more than 250 pounds per square inch is the necessary material.

Propelling and metering devices: A metering piston pump or an orifice is commonly used to control the discharge rate. An orifice can be regulated by hand valve or by a pressure-regulating valve.

Distributing devices: Applicator tools of chisel or knife type are required to dig furrows for the liquid. A pipe with discharge outlet is attached to the blades. A press wheel or slide is usually needed to firm the soil cover over the deposited fertilizer. These tools may be tractor attachments.

For low-pressure nitrogen solutions. . .

Containers: Mild steel is advisable for solutions of aqua ammonia; aluminum or stainless steel alloys for other solutions.

Propelling and metering devices: A metering piston pump or metering hose pump is advantageous to control the application rate uniformly. However, if tractor speed can be kept uniform, one of the following is satisfactory: an impeller pump of gear, centrifugal, or roller type; an air compressor pump, which can be attached to the tractor power take-off; a gravity flow system.

Distributing devices: Cultivator shovels or disk harrows can be used to cut and cover shallow furrows when applying low-pressure liquids. Distributor orifices or nozzles of different sizes are necessary when using any of the propelling devices listed above except the hose pump. These orifices or nozzles, which serve as line restrictions, insure uniform distribution of the liquid among the hoses.

For nonpressure liquids--mixtures and single nutrients. . .

Containers: Metal or wood barrels may be used for mixed liquid fertilizer. For phosphoric acid alone, metal containers with rubber or plastic lining or stainless steel or wood containers are suitable; for nitrogen solutions, aluminum alloys or stainless steel.

Propelling and metering devices: For surface or sub-surface use, these may be of the same types as those suitable for low-pressure liquids.

Distributing devices: For ground use, these may be of the same types as those for low-pressure liquids. If liquid is dribbled on ground surface, discharge tubing and dribble tubes can be tied to a boom on the tractor. For spraying on ground surface, a field sprayer used in weed or other pest control is suitable provided it is made of non-corrosive metals. No copper-bearing metals should be used with nitrogen solution fertilizers.

TIMING PRACTICES

Splitting applications of nitrogen and applying fertilizer to soil in the autumn are two of the newer techniques that may be effective in certain circumstances with liquid fertilizers, as they are with solid fertilizers.

Split Application of Nitrogen

Splitting an allotted quantity of nitrogen into two or more applications suits plants that have large nitrogen requirements. The method is advantageous for these plants when they are grown in poorly drained soils where nitrates may be converted to gases and lost from the soil and in soils from which nitrates leach rapidly out of the root zone. This leaching is most likely to occur in sandy soil where the rainfall is high or irrigation is-practiced.

In splitting a nitrogen allotment, the number of applications and the timing need to be adjusted to the crop. For example, corn benefits from side dressing at time of last cultivation. This insures a large nitrogen supply when the corn needs it most--from the time when the corn is about 2 feet high until tasseling.

Leafy crops, such as broccoli and cabbage, benefit by getting part of their nitrogen allotment after they grow so large that fertilizing implements cannot pass through the field. At this stage, liquid nitrogen can be applied by sprinkler irrigation. If this is done, the nitrogen treatment should be followed by a clear water spray to remove residue that might burn foliage.

Fall Application of Liquid Fertilizer

Favorable climate and soil are essential for success when fertilizer is applied in autumn to be ready for crop use the following spring. In some climates and soils there is so much loss of nitrogen that fall fertilization is of doubtful value or definitely unsuitable.

Provided conditions are suitable, fall fertilization has certain advantages: Farmers can get fertilizer orders filled more readily and sometimes more cheaply than during the spring rush season. Fall application may be a thrifty alternative to investing in storage facilities.

ARS soil scientists show in figure 1 areas in which the risk of nitrogen leaching out of the soil ranges from none at all to a high proportion. The mapping is general and does not allow for local variations in soil permeability which might alter recommendations. The mapping serves mainly to call attention to the need to consider climatic conditions carefully before choosing fall application.

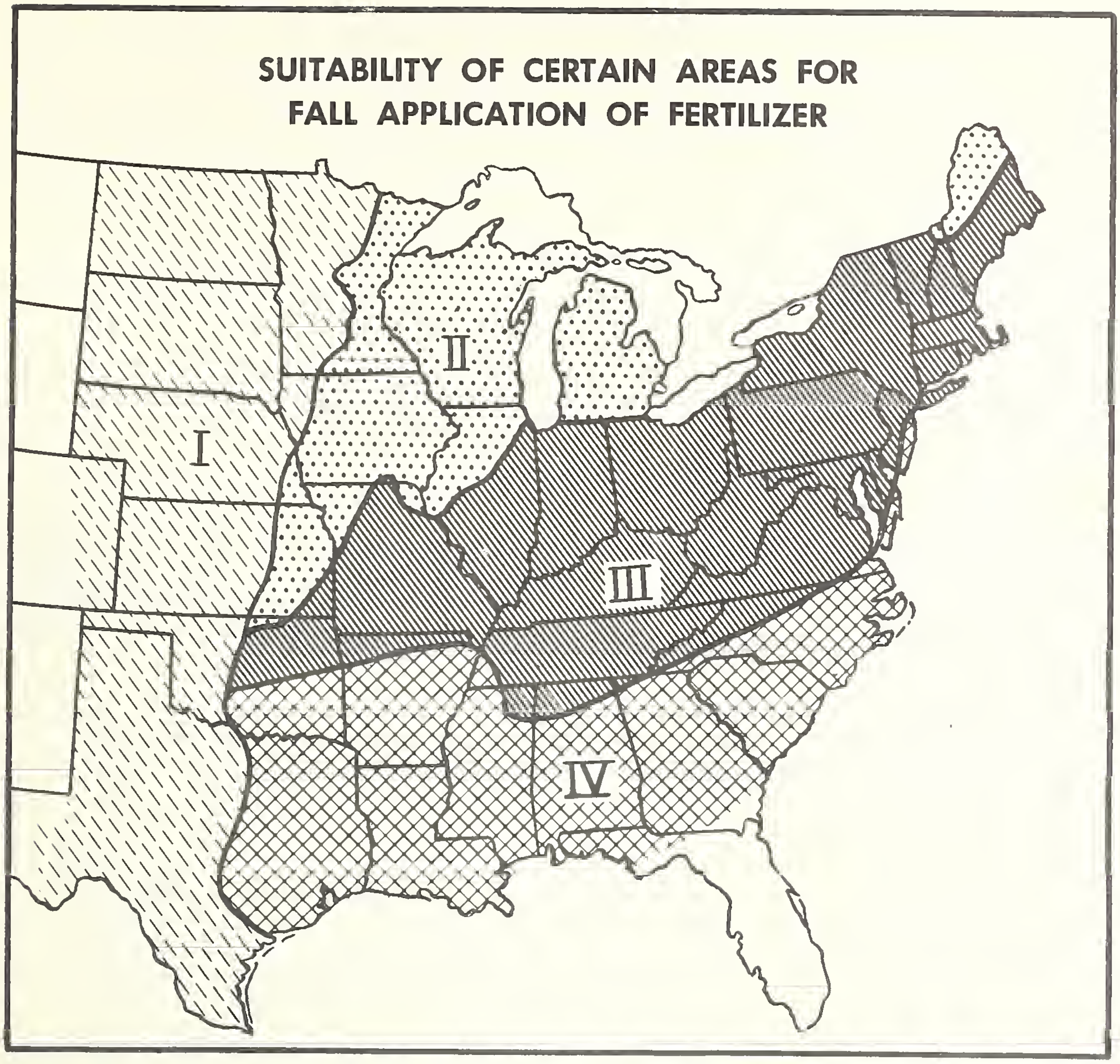
SUITABILITY OF CERTAIN AREAS FOR
FALL APPLICATION OF FERTILIZER
I
II
III
IV

Figure 1.--Area I is the most suited to fall application. Except in years of very heavy rainfall there would be little or no nitrogen loss from percolation or leaching.

Area II ranks second in suitability. Where rainfall is greatest within this area, risk of nitrogen loss would be greatest, particularly if a nitrate form were used. Where fall temperatures are low, this offsets somewhat a rainfall disadvantage because the coolness of the soil retards conversion of ammonia-nitrogen to leachable nitrate forms.

Area III receives more rainfall than I and II. Fall application would be of doubtful value, and particularly so in the South.

Area IV is not suited to fall fertilizer application because of its still greater rainfall combined with high temperatures.

TRENDS IN USE

In 8 years, the tonnage of liquid fertilizers used on this country's farms has increased 1,651 percent--from 40,529 tons (not including mixtures) in the year ending June 30, 1947, to 709,836 tons in 1954-55. (See table 3) No data on mixtures are available for 1954-55; an estimate for 1953-54 is given in a footnote to table 3

Use of Nitrogen in Liquid Forms by States

Nitrogen content of all farm fertilizers--liquid and solid--that were marketed for direct application in Continental United States and Territories

Table 3.--Quantities of commercial liquid fertilizers used in the United States and Territories

Liquid fertilizer	Quantity for year ending June 30--	
	1947	1955
	Short tons	*Short tons*
Anhydrous ammonia	27,314	353,681
Nitrogen solutions[1]	7,328	340,574
Phosphoric acid	5,887	15,581
Mixed fertilizers	6,607	(2)
Total	47,136	709,836

[1] Includes aqua ammonia.

[2] Figures for 1954-55 not available; usage in Continental United States in 1953-54, 27,548 tons.

in 1954-55 totaled 1,156,995 tons. Of this nitrogen tonnage 32.4 percent was applied in the forms of anhydrous ammonia and aqua ammonia and other nitrogen solutions. The map in figure 2 indicates the extent to which these liquid forms of nitrogen are used in the different States and Territories.

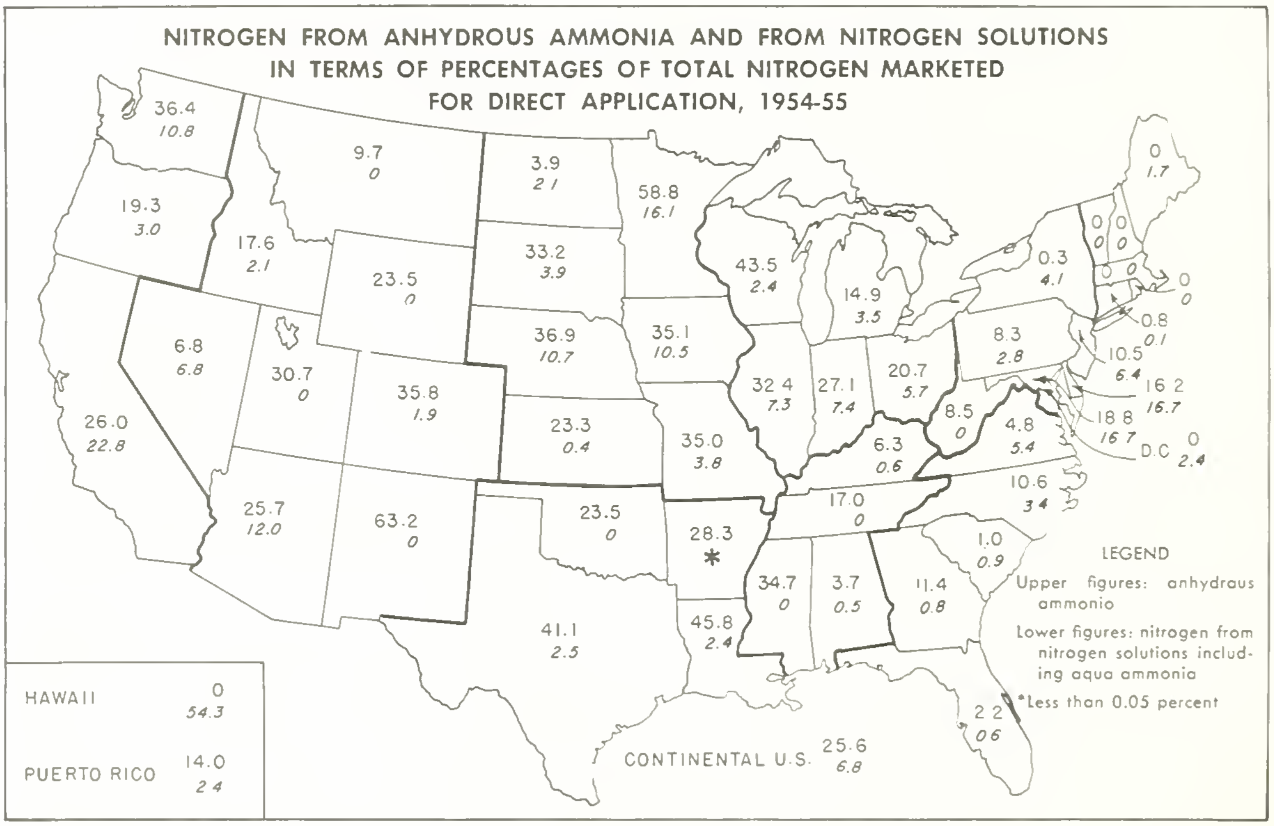

Figure 2.--Proportions of farm-applied nitrogen that is supplied by liquid nitrogen-bearing products vary widely--from none in most of the New England States to 74.9 percent in Minnesota. The average for the United States and Territories is 32.4 percent, of which 25.1 percent is supplied by anhydrous ammonia nitrogen and 7.3 percent by the other liquid nitrogen forms.

Anhydrous Ammonia

Anhydrous ammonia has consistently outranked other liquid fertilizers in farm use, and in 1954-55 accounted for nearly 50 percent, as shown in table 3.

In 1946-47, use of anhydrous ammonia was reported in only 3 States--Arizona, California, and Mississippi. In 1954-55, it was used to varying extent in 43 States--that is, in all except Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and the District of Columbia. The first reported use of this fertilizer in New England farming consisted of a few tons in Connecticut in 1952-53.

Almost two-thirds of the anhydrous ammonia is marketed in 3 regions: West North Central--23.0 percent; Pacific--21.7 percent; West South Central--19.2 percent.

Following are anhydrous ammonia fertilizer tonnages used in States of these 3 regions, and the regional totals, for 1954-55:

Iowa	17,882
Kansas	8,523
Minnesota	15,474
Missouri	14,978
Nebraska	22,766
North Dakota	134
South Dakota	1,695
West North Central region	81,452
California	51,518
Oregon	7,069
Washington	18,289
Pacific region	76,876
Arkansas	15,026
Louisiana	23,757
Oklahoma	1,794
Texas	27,158
West South Central region	67,735

For a number of years, anhydrous ammonia was applied primarily in irrigation water. Now, however, the greater part of the tonnage is soil injected. Expansion of farm use of anhydrous ammonia is expected to continue, though the rate of increase has slackened. This liquid fertilizer is gaining favor particularly in States such as Illinois and Iowa for corn crops. Considerable amounts of anhydrous ammonia are being applied to cotton throughout the South.

Nitrogen Solutions

Farm use of low-pressure and nonpressure nitrogen solutions is rapidly expanding in contrast with use of anhydrous ammonia, which has been leveling off after rapid advance. The nitrogen solutions do not require high-pressure equipment, which may account in part for their current expanding trend.

Total use of the nitrogen solutions increased from 72,917 tons in 1952-53, to 191,592 tons in 1953-54, to 340,574 tons in 1954-55.

The nitrogen solution called for in greatest quantity is aqua ammonia (anhydrous ammonia diluted with water). Aqua ammonia represented 68.1 percent of the nitrogen solution tonnage in 1954-55.

The outstanding market for nitrogen solutions has centered in the Pacific region; but demand is spreading, and tonnage gains in the North Central region have been particularly rapid.

Following are State, Territorial, and regional tonnages of nitrogen solutions (including aqua ammonia and other low-pressure solutions, and nonpressure solutions) for the 4 regions using greatest quantities in 1954-55:

California	169,599
Oregon	3,327
Washington	21,936
Pacific region	194,862

Hawaii	42,833
Puerto Rico	1,730
Alaska*	---
Territories	44,563

*Not available

Iowa	11,126
Kansas	326
Minnesota	8,457
Missouri	3,476
Nebraska	13,815
North Dakota	141
South Dakota	394
West North Central region	37,735
Illinois	10,560
Indiana	6,261
Michigan	858
Ohio	1,726
Wisconsin	315
East North Central region	19,720

Phosphoric Acid

Phosphoric acid as a separate liquid has been applied to crops chiefly in irrigation water. Phosphorus in this form is expensive to produce. Hence, the farmer generally pays more per unit for the nutrient than if he used the commonly applied solid phosphatic fertilizers.

Aside from convenience in irrigation farming, phosphoric acid has no special advantage over solid forms of the same plant nutrient, and demands for this separate liquid product are not expected to expand greatly.

Liquid Mixed Fertilizers

In California, where the liquid mixtures have had greatest use, farmers could buy 67 grades in 1953-54. The latest available State reports on liquid mixtures indicate that 27,548 tons were used in 1953-54. At that time, 80.7 percent of the mixture tonnage was marketed in the Pacific region. Facilities for manufacturing liquid mixed fertilizers have been expanding, particularly in the North Central as well as in the Pacific region. Present use of the mixtures is believed to be much larger and more extensive than the 1953-54 figures indicate.

LIQUID FERTILIZER PRODUCTION

Early in 1956, anhydrous ammonia was being produced in 43 plants in the United States. Their total capacity was estimated at about 3,353,000 tons of nitrogen a year. In addition, 7 plants were known to be under construction. With the addition of these plants, each region of the country will have at least one production center.

Facilities for producing low-pressure nitrogen solutions, as of July 1955, were located at 17 of the anhydrous ammonia plants, and additional facilities will be provided at anhydrous ammonia plants under construction.

In April 1955, liquid mixed fertilizers were being produced at about 144 plants, the majority in the Pacific and East North Central regions.

Expansion of facilities for liquid fertilizer production is making the liquids available as new products in some areas. Anhydrous ammonia has such high nitrogen content that it can be shipped long distances without excessively increasing the unit cost of the nitrogen; the other liquid fertilizers with lower nitrogen content cannot.

LEGAL REQUIREMENTS

Sale of liquid fertilizers is regulated by State authorities that control the sale of other fertilizers within the State. In most cases, a liquid fertilizer must be registered with the proper State authority and a guaranteed analysis given. States generally require that the product conform to this guaranteed nutrient content and that the analysis be stated on the container or invoice.

Besides regulations concerning the liquid materials themselves, detailed regulations have been issued by many States dealing with storage, transportation, and applicator equipment for the high-pressure anhydrous ammonia--for personal protection of all concerned. Some of the regulations can well be followed for greater safety in handling low-pressure liquid fertilizers also. In general, the State regulations are based on precautions recommended by the American Association of Mechanical Engineers and the Compressed Gas Association.

While the regulations primarily concern dealers and others in the fertilizer industry, a prospective user of pressure liquid fertilizers is advised to consult his State fertilizer control official or county agricultural agent for information about any transportation, storage, or equipment restrictions with which he should comply.

SAFETY

Properly handled, liquid fertilizers under pressure are as safe to use on a farm as other commonly used materials, such as gasoline. Following are precautions to be observed by persons using liquid fertilizers--

*Avoid breathing ammonia fumes.

*Avoid contact with liquid ammonia because it can severely burn skin, eyes, and linings of nose and throat.

*Do not put ammonia in a container for a household fuel, such as butane or propane, if it is to be used again to hold heating or cooking fuel. Poisonous gases may be formed.

*Never apply an open flame to equipment for handling anhydrous ammonia or a nitrogen solution unless the equipment has been thoroughly cleansed of all contents, including sediment and deposits. Otherwise, danger of explosion is great. It is advisable to have a qualified service man handle such repair work if it is needed. Non-corrosive material in equipment greatly lessens the likelihood that such repairs will be required.

RESEARCH NEEDED

With the expanded use of liquid fertilizers comes need for more information furnished by research, in order to improve the production and use of these farm materials. For example:

There is need for more extensive research, dealing particularly with anhydrous ammonia and aqua ammonia, on: placement of liquid fertilizers in relation to seeds, plants, and crop residues; fall versus spring application; relative effectiveness of the fertilizers when applied before and after the crops emerge.

To improve liquid mixed fertilizer production, there is need to expand study of: mixed fertilizer formulations to determine what materials are compatible for use in high-analysis products; ways of incorporating secondary and minor elements; ways of preventing potash salting out; economic methods for using wet-process phosphoric acid in liquid mixed fertilizers.

Improving application equipment for liquid fertilizers is seen in need of more extensive research attention.

Agriculture - Washington